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DESIGN OF THE ENERGY NETWORKS IN A SUSTAINABLE DISTRICT

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INTRODUCTION

The paper presents the activity that will be carried out in a district of the city of Torino, Italy, inside the Integrated Project POLYCITY, approved in the Sixth Framework Programme - Priority 6.1 - Sustainable Energy Systems. The POLYCITY project features sustainable energy concepts for very large urban development areas and thus strongly contributes to reducing primary energy consumption and CO₂ emissions. The special efforts to integrate building energy demand reduction and renewable energy supply sources using polygeneration technologies is a main requirement of the CONCERTO initiative. The overall project involves several partners from various European Countries, and its main applications will be developed and installed in Spain, Germany and Italy. The POLYCITY project will start in 2005 and will have a duration of five years. The project focuses on large scale urban developments, where living and working areas are integrated to result in sustainable city districts with short distances and low energy consumption. The overall project deals with different aspects of urban conversion, such as new constructions on sites with little development at the city edges of Barcelona (Spain), conversion of an old city district in Torino and a mixture of rehabilitation and new construction on a large military ground near Stuttgart (Germany). The project is integrated in a regional sustainable development strategy.

POLYCITY: THE ITALIAN CONTRIBUTION

The Italian application project is an additional part of the modernisation and requalification project of a district of the city of Torino (named Arquata district), comprising 30 residential council houses and the commercial building hosting the Housing Authority of the Province of Torino (ATC), which owns and develops the whole district (Fig. 1). In particular, the activity will be aimed at improving the energy efficiency and quality of life of the district. The measures foreseen concern the supply side and the demand side, both for the residential and for the commercial buildings. The most innovative part is the realisation of a pilot system for the telematic control, that will act as an integrated energy planner and manager for the Arquata area. This pilot system will be conceived for monitoring all energy flows within the site and the distribution grid, for planning local energy production based on simulation models and for optimising management regarding efficiency, quality and safety. The consortium of the Arquata project in POLYCITY involves all the relevant stakeholders, such as ATC, the local utility for energy distribution and sale (AEM), centres of competence/research centres (CRF and Politecnico di Torino),

the Municipal Administration for the dissemination of results and the Regional Administration.

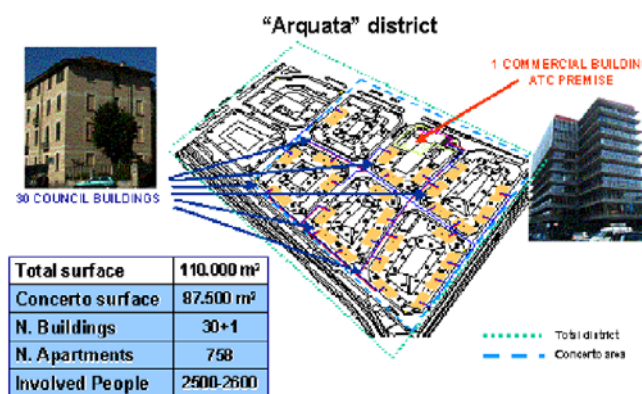


Fig. 1. Scheme of the Arquata district

Arquata district

Arquata is a densely populated district, constituted by 30 large council buildings built at the beginning of the 20th century and by a 10-floor commercial building built in the 1970's, which is the main premise of ATC. Arquata is located close to the city centre of Torino, but it is isolated from the surrounding urban areas by physical barriers such as two railway tracks and one bridge. The physical isolation generated a progressive social separation and marginalisation of the district.

Social and occupational situation became critical and was accompanied by a progressive urban deterioration. Local services and economical activities have always been absent. The demonstration site for POLYCITY covers an area of 87 500 m² with 758 dwellings. The population involved is between 2500 and 2600 persons, of which 2200–2300 are inhabitants of the council buildings and 300 are employees of ATC. A requalification project for additional 20000 m² in the same area is actually under discussion. ATC owns and manages approximately 37000 units, of which 33000 are apartments and the others commercial.

Main innovative features on the demand side

The different measures foreseen on the demand side aim at reducing and shifting energy consumption. However, the requalification project introduces a substantial increase in the services of the area, some of which imply an additional energy demand. Measures such as the introduction of space

heating in all council buildings, the installation of elevators and the increase of lighting in common spaces would increase the overall energy consumption, so that appropriate countermeasures on energy demand and on system integration are required. The following measures will be implemented:

- extra thermal insulation for the 30 council buildings;
- substitution of the windows in the 30 council buildings using double glazing;
- insulation of the NE glazed façade of the ATC building (double façade);
- installation of photovoltaic modules on the SW and SE façades of the ATC building as solar shading systems;
- high efficiency lighting in internal common spaces in the council buildings.

District heating network

Among the different measures already approved, the District Contract requalification programme includes a district heating distribution network for Arquata aimed at providing all the council buildings with space heating and sanitary water where previously it was lacking or there were only inefficient small electrical and fossil-fueled boilers. The final result will be a substantial improvement in the quality of life for the inhabitants due to the increase in comfort and services.

Main innovative features on the supply side

The different measures on the supply side aim at achieving energy efficiency through system integration. To supply district heating and electricity demand in the most efficient way, gas fired co-generation will cover the bulk of the energy demand [1] [2]. The co-generation unit is heat-demand driven, so that additional solar thermal energy would reduce the co-generation unit operating hours and thus reduce economic operation. However, to have a share of renewable energy, the high rise once building will integrate multifunctional photovoltaic panels as sun-shading devices. The energy efficient energy supply system will contain:

- a natural gas modular co-generation plant (0.9 MWe_{el}, 1.1 MW_{th}) to be installed in the ATC commercial building;
- an absorption chiller, thermally coupled to the co-generation plant [2][3], placed in the ATC commercial building that will provide cooling energy for climatization of the ATC building itself;
- modification of the district heating distribution grid to provide heat storage for peak management;
- photovoltaic modules to be integrated in the façade of the ATC commercial building as Sun-shading devices with a total peak power of 50 kW;
- additional photovoltaic modules to be installed on the roofs of the council buildings with a total peak power of 100 kW.

The excess electricity produced by the co-generation plant will be provided to the distribution grid. ATC will install telematic electricity meters for each of the customers/exchange points with the distribution grids in order to monitor all the electricity flows in the Arquata area.

The design of the co-generation plant will consider different modularisation options in order to identify the most suitable

solution in terms of flexibility, reliability and efficiency of operations, yearly use of the plant, ease of maintenance.

Another important feature that will be implemented and tested in the ATC building is the use of the co-generation plant as backup power unit for the loads that can not be interrupted (e.g., data centres, elevators, etc.). Actually UPS systems powered by diesel gensets are installed. The utilisation of a co-generation unit as a backup power is quite innovative for such purpose with respect to the state of the art and requires appropriate design and strategies for control devices and power electronics components.

Measures for integration of supply and demand

The pilot system for the telematic control is conceived to act as an integrated energy planner and manager for the Arquata district. It aims at studying the feasibility and the solutions for implementing a physically independent and integrated energy system for the entire district, to be self-sufficient in terms of energy production and optimised in terms of energy management.

The main features of the pilot system will be the following:

- Monitoring all energy flows within the site and the distribution grid;
- Local energy production planning based on simulation models (demand profiles, market prices, energy full costs);
- Simulating operation as an independent integrated energy system with net exchange with the distribution grid;
- Optimising management of the entire Arquata district with respect to efficiency, quality, safety, and costs.

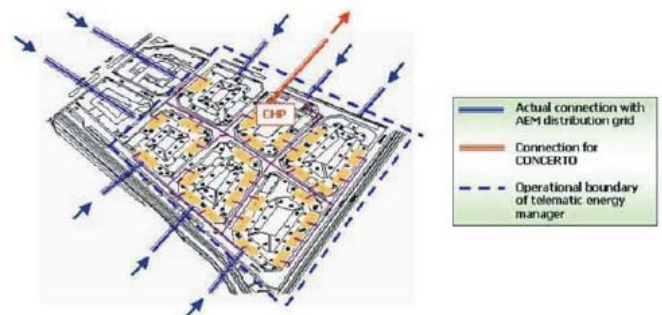


Figure 2: Concept of an integrated energy system for the Arquata district.

The integration challenge in the Italian project is the combination of co-generation and photovoltaics. The operation of the co-generator is heat driven, so that it cannot contribute to power peaks levelling of the district if the council buildings draw more electricity from the grid than the PV systems production. Such peaks cause increase in costs and emissions for the electricity distribution utility and should be avoided whenever possible. A simulation study of the effects of different architectures for the internal grid, of different solutions for the interconnection with the distribution grid, and of different control strategies will be carried out before making the investment. The objective is then to study and identify the best solution for a subsequent implementation. In this context the owner of the site (ATC) and the local utility (AEM) partners are mainly interested in:

- evaluating the feasibility and return of investments of implementing a dedicated physical internal grid for the

Arquata district, to be supplied by the local co-generator and by the photovoltaic modules and connected to the external grid by a limited number of exchange nodes;

- evaluating the benefits for the municipal energy system (environmental, peak management, distribution costs etc.) deriving from the integrated energy system;
- defining the specifications (technical and contractual) for outsourcing the integrated energy services to an energy supply company;
- evaluating the business opportunity of such an application for an energy supply company.

In terms of technologies, CRF intends to implement the Integrated Energy Manager by customising technologies derived from automotive applications. In particular a telematic platform actually used for the fleet management of ecological vehicles (CNG fuelled and hybrid) will be customised.

ENERGY MANAGEMENT SYSTEM

For the effective implementation and operation of the Integrated Energy Manager Infrastructure, it is necessary to foresee an adequate monitoring of all the energy flows inside the area [4], like:

- telematic electricity meters for each of the customers/exchange points with the distribution grids;
- telematic water meters for all the council buildings;
- telematic meters for space heating in every dwelling of the council buildings;
- emission and energy input sensors at the co-generation plant. All the mentioned signals will be acquired by a telematic system that will give input to the Integrated Energy Manager.

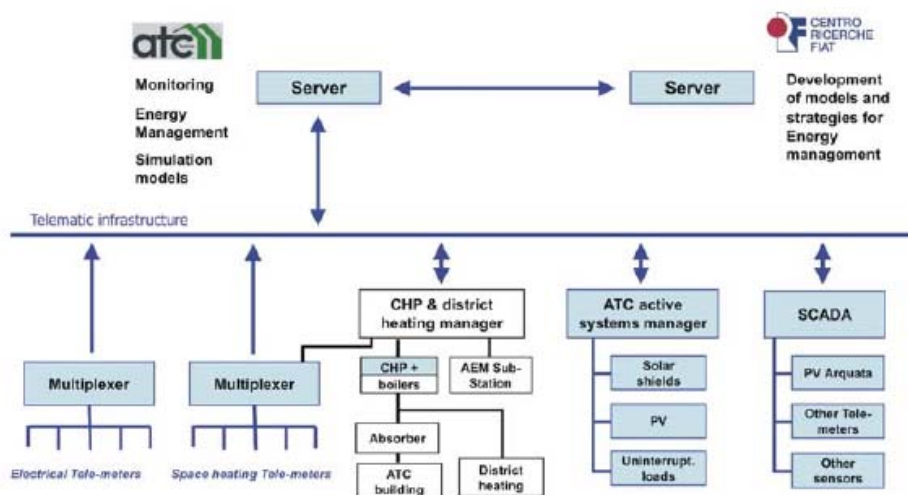


Figure 3: Concept of telematic infrastructure for energy management.

Control strategies

A model-based control strategy will be implemented. On the demand side, simulation models for predicting the (thermal and electrical) load profiles [5][6] of the council buildings and of the ATC building will be developed and validated.

On the supply side, simulation models for the co-generation plant [2][7][8][9], for the distribution grid [10] and for the photovoltaic modules [11] will be developed and validated. Finally, a simulation model for the energy costs will be customised (price markets, full costs, etc.). Among the functions of the Integrated Energy Manager there are an energy planner, an energy manager, and a business evaluator. The energy planner will be designed to determine the most convenient production plan based on the above models and using a multi-criteria optimisation algorithm jointly developed by CRF and Polito. Such a production plan is intended to define on a weekly base the inputs to all the controlled systems of the Arquata district. It will be automatically generated as a file containing all the settings in a protocol compatible with the telematic system.

The energy manager will be designed to compare the actual demand and the production parameters and to determine eventual modifications. These modifications will be automatically generated and sent through the telematic system at a rate compatible with the functionality and with the costs (tentatively every quarter of an hour). The business evaluator will be designed to evaluate the expected profitability of the integrated energy system of different technical and operational configurations of the site.

SOCIO-ECONOMIC ISSUES

The Italian POLYCITY team will carry out a socio-economic study regarding the Scope and objectives following aspects:

- quality of life and added value created by the Arquata project;
- risk perception of the innovations introduced in the service and in the plant technologies;
- involvement and participation of the citizens;
- local situation and trends in energy costs, prices and savings.

Participants with different roles in the environmental and in the social change will be considered and involved. The following objectives will be pursued:

- to define criteria and indications for reinforcing the sustainability of the innovations proposed in a larger terms (not only economical);
- to carry out the assessment of the technological and market risks related to the implemented measures;
- to study and compare the differences between the application projects in the different European regions in terms of social context, countries, cultures, environmental concern, attitude to innovation, categories of final users and population.

Existing competence and methodologies matured in other application fields (e.g. mobility) will be applied for the assessment of perceived quality aspects of services in the civil field in a cross-fertilisation approach. Social aspects will be analysed by using appropriate methodologies and related methodological approach techniques, such as qualitative ones (i.e., focus group, in-depth interviews, observational methods) and quantitative ones (i.e., questionnaires, diary method). Subjective data will be correlated with objective ones to verify the validity of the results, to have an exhaustive and complete image of the local situations and give the possibility of implementing suitable performance indicators.

In general, the approach will be to customise existing methods from similar and/or different application sectors. In particular, among the partners CRF intends to bring out its competence in the assessment of perceived quality of services related to mobility applications. Such competence will be used to customise existing methodological tools (questionnaires, indicators, statistical analysis, etc.) and market and social segmentation.

The socio-economic activity will be structured in five main steps:

1. definition of a preliminary framework for the assessment;
2. assessment of the socio-economic aspects before the requalification project takes place;
3. refinement and consolidation of the framework;
4. assessment of the socio-economic aspects during the implementation and operation of the requalification project;
5. comparison of the results and methodological consolidation.

DEMONSTRATION IMPACT

The project will start in the first semester of 2005. Some activities have been started in 2003 and developed in the 2004. The energy impact of the POLYCITY application in the Arquata district has been predicted by simulations and the calculated energy savings are reported in Table 1.

CONCLUSIONS

The design of a comprehensive energy network to be applied to the refurbishing of a urban district calls for a careful study involving several aspects in the technical, socio-economic and environmental fields. The design of the energy network that will be implemented in the Arquata district allows for

foreseeing promising energy and environmental savings, in spite of a slight increase in the electricity demand. Once the energy network will be realised, the district will benefit of new facilities for monitoring and operating the energy system more efficiently, as key value-added services for the energy provision and management and for the improvement of the energy efficiency and quality of life.

TABLE 1. Energy demands and savings

| Energy consumption | Before POLYCITY | After POLYCITY | Savings |
|---------------------------|-----------------|----------------|---------|
| <i>Council buildings</i> | | | |
| Heat demand | 17 150 MWh | 8 100 MWh | 53% |
| Electricity demand | 4 900 MWh | 5 280 MWh | -8% |
| <i>ATC offices</i> | | | |
| Heat demand | 1 300 MWh | 1 300 MWh | |
| Electricity demand | 980 MWh | 980 MWh | |
| Cooling demand | 500 MWh | 260 MWh | 46% |
| Primary energy | 39 400 MWh | 21 100 MWh | 46% |
| CO ₂ emissions | 11 820 t | 6 630 t | 46% |

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